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The American Association for the Advancement of Science:
The Living Globe: PROFESSOR BAILEY WILLIS 427

Scientific Events:
The Western Division of the Connaught Laboratories; The Lawrence Hopkins Memorial Experimental Forest; The Reorganization of the Department of Vital Statistics of the U. S. Bureau of the Census; The United Engineering Trustees; Meetings of Geologists in New York City. Recent Deaths 433

Scientific Notes and News 435

Discussion:
The Born Theory of the Electron: DR. ARTHUR BRAMLEY. *The Question of Wildlife Destruction by the Automobile:* DR. W. A. DREYER. *Is a Pace-maker Involved in Synchronous Flashing of Fireflies?:* PROFESSOR GORDON ALEXANDER. *The First School of Chemistry:* DR. PHILIP E. BROWNING 438

Scientific Books:
The Alligator: DR. ALBERT M. REESE. *Aeronization in Medicine:* J. W. PINCUS 441

Special Articles:
Bacterial Content of the Air at High Altitudes: DR. GEORGE WALKER. *On the Nature of Filterable Viruses:* DR. ROBERT G. GREEN 442

Scientific Apparatus and Laboratory Methods:
A Simple Method of Determining Areas in Microphotographs: RONALD L. IVES. *A Method of Preparing Skeletons of Small Vertebrates:* DR. ROLF L. BOLIN 445

Science News 8

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THE LIVING GLOBE*

By Professor **BAILEY WILLIS**

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Dynamics is the soul of the problem.
—*T. C. Chamberlin.*

DURING the nineteenth century, geology, dependent on physics, knew but one ultimate terrestrial force—gravity. Gravity, the conservator of established relations, was the cause of all disturbances in any effort to restore any dis-established relations. He held continents and ocean basins in balance, in spite of erosion and sediment; he raised mountain chains by contracting the earth and wrinkling the crust; he pulled the globe constantly toward the center and transformed the energy of in-fall into heat; and since the heat escaped he thus cooled the earth, pointing to a dark and chilly future. Similarly, he was the source of all heat in the sun, and the life-giving energy of that luminary was definitely limited. There was enough truth in these ideas to command credence, and yet they so narrowed the possibilities of pre-historic geology and cosmogony, not to mention the denial of future opportunity, that they were found wholly inadequate. When Chamberlin challenged Lord Kelvin's estimate of twenty to forty million years as the probable past of the earth he argued for the strength of geologic evidence as opposed to the weakness of imperfect, incomplete knowledge of natural forces.[1]

The discovery of radioactivity and of the general occurrence of radioactive minerals throughout the accessible rocks, though in very minute quantities, opened new possibilities to geologic theory. Here was a source of atomic energy, quite independent of gravity and abundantly able to supply heat for indefinite periods of time. Geologists were slow, however, to avail themselves of this potent energy. Chamberlin in 1911 welcomed the opportunity thus afforded for

* Address of the retiring president of the Pacific Division of the American Association for the Advancement of Science, Los Angeles, California, June 25, 1935.

[1] T. C. Chamberlin, SCIENCE, n. s., Vols. 9 and 10, 1899.

development of alternative hypotheses of earth history, but did not formulate a comprehensive theory.[2] Arthur Holmes, of Durham, in 1915 essayed to reconstruct the thermal history of the earth on the assumption that it is a cooling globe, which has been losing heat for 1,600,000 years. He discarded the idea that the earth might be getting hotter and was obliged to assume that radioactive elements had become concentrated chiefly in the crustal rocks. The well-known work of Joly, "The Surface History of the Earth," appeared in 1925. It presented an argument for repeated melting and alternate solidification of a shell below the outer crust and is a very suggestive work. In 1928 Holmes, having found his ideas of 1915 untenable, proposed a new theory, which recognizes the presence of radioactive elements beneath the crust, to a depth of 2,900 kilometers, uniformly distributed but in very minute quantities. To dispose of the accumulating heat he assumes a stirring by convection currents and escape by conduction through thin portions of the crust.[3] Among American thinkers Barrell and L. H. Adams have offered constructive ideas. Both inclined to recognize an irregular distribution of radioactive elements and reasoned that the effects of heating would be local, not general. Barrell's thought unfortunately never attained development as a complete working hypothesis, and Adams has not generalized beyond the statement that variations in radioactive content would result in local melting and might maintain a locally high temperature almost indefinitely.

In 1931, on reviewing the hypotheses framed to elucidate the possible thermal history of the globe, I suggested that the difficulties which Holmes, Joly and some others had encountered were due to the assumption that radioactive elements were so distributed as to produce uniform heating in the mass or in some particular shell. It seems to me quite unnatural and inconsistent with geologic and geophysical data to assume homogeneity of constitution for any considerable mass or shell of the earth and therefore more rational to start with the assumption of heterogeneity.[4]

In the meantime our knowledge of conditions in the interior of the earth has grown apace. Those swift and penetrating scouts, the elastic waves from earthquake shocks, bring word of the conditions they have encountered in coursing through the depths or in traversing an outer shell. From them we learn that the going is good anywhere between the surface and a depth of 1,770 miles (2,850 km).[5] Rocks to that depth are highly elastic. But beyond is something different. They can not get through the central sphere, the substance of which is inelastic.

We have no word to describe a state of matter which is characterized by inelasticity except we say fluid. But the core of the earth—for that is what the sphere in question is—is so dense and so stiff that "fluid" conveys a false notion of mobility. The material is nearly as heavy as lead, probably flows much less easily and is supposed to consist chiefly of nickel, iron and other heavy elements. The inelastic condition of such substances is attributable, so far as our experience goes, only to melting, and a molten condition under the enormous pressure of the interior requires very high temperature. Hence we may conclude that the core is very hot.

How did the core become so hot? Here we begin to speculate less surely, and the paths of thought diverge backwards as well as forwards. If we incline to follow the astronomers and mathematical physicists, who argue that the globe once passed through a completely molten condition, we may recognize in the molten core of the earth a residual body which has never cooled. Or, if we think, as Chamberlin did, that the globe was solid from the beginning of its growth as a planet, we may reason that the interior has become heated by compression by gravity or that it has grown hotter through the disintegration of radioactive elements.

The assumption that the globe was once wholly molten is still generally accepted, though it is no longer so imperative as it seemed to be before radioactive heating was recognized. It appeared to get a setback when L. H. Adams suggested that any crust which had formed by cooling of the surface must sink into the lighter melt and accumulate in the depths, so that the globe would solidify from within outward. But even so, the depth to which blocks of crust might sink would be limited by still heavier, though molten layers, and the core might become enclosed in a solid shell, as it now is. I see no cogent objection to that view, although I do think Chamberlin's analysis of the conditions attending the separation of the earth from the sun was more complete and accurate than that which leads astronomers to infer a molten globe in lieu of the solid one that he conceived. But that is another question. The molten core may be a residual molten body, enclosed in an outer shell that is thick enough to have prevented the escape of heat, or it may have been so supplied with heat by compression and feeble radioactivity that any escaping energy was replaced and the body has not been cooled.

On the other hand, if the globe assembled by the gathering of sun-dust according to Chamberlin's planetesimal hypothesis, the core presumably con-

[2] T. C. Chamberlin, *Jour. Geology*, 19: 673–695, 1911.

[3] Arthur Holmes, *Trans. Geol. Soc. Glasgow*, 18, Pt. III: 559–606, 1928; *Jour. Wash. Acad. Sci.*, 23: 169–195, 1933.

[4] Bailey Willis, *Am. Jour. Sci.*, Vol. 23, 1932.

[5] B. Gutenberg, *Gerland's Beiträge*, Bd. XVII, p. 365, 1927; J. B. Macelwane, S.J., *Bull. Seis. Soc. Am.*, 14: 81–89, 1924.

sisted of heavy elements, among which radium and other radioactive substances would be expected to occur. Whatever its initial size might have been and however small the proportion of heat generators, the temperature of the central body would be raised after it had become sufficiently mantled to prevent escape of heat as fast as it accumulated, and a molten condition would eventually ensue. It appears from the estimates of Holmes, Joly and Jeffries that the two thousand million years which the solid earth surely counts would have afforded quite sufficient time to melt the core. Any such calculation is, of course, a guess, for we can assume such a proportion of radioactive elements as will nicely have done the work, or we can assume less favorable conditions. The essential fact is that the melting can be attributed entirely to radioactivity without postulating improbabilities.

Whatever the past may have been, I regard it as probable that the melting process has not ceased in the interior. The reason for thinking that it continues is the sharpness of the boundary that separates the core from the elastic shell which surrounds it. Earthquake waves of the elastic type locate the limit to which they can penetrate and beyond which they fade away into the inelastic core within 12 to 20 miles (20 to 30 km). That is to say, they fix the radius of the core within 1 per cent. Inside of that very thin transition shell is a molten sphere. Outside of it is the mantle of highly elastic, solid rock. The latter is no doubt hot, but not melted. The condition can not be a stable one. The dynamic core is either losing or gaining heat, is either shrinking or increasing in diameter.

To explain this actual condition there are the two distinct lines of inference already suggested. Starting with a molten earth we may imagine the blocks of crust sinking to a certain depth, remelting there and thus absorbing heat. Continued formation of the crust and continued remelting of sunken blocks would in time solidify an outer shell, while the interior would cool very slowly. We may be observing a stage of that process.

On the other hand, if the globe had a smaller molten core originally or had initially been entirely solid but contained a small proportion of radioactive elements, the continued generation of heat would melt it from within outward. It is not necessary to suppose the heating elements uniformly distributed. Foci of energy would develop local bodies which would eventually coalesce. A molten interior, such as we observe, would result.

At this stage of speculation it becomes necessary to consider the probable manner of distribution of the radioactive elements in the beginning and the changes which have presumably occurred. In the molten state of the globe the heavier elements would sink and the lighter rise. Heavy radioactive elements would tend by gravity to assemble in the depths, but, since they heat up and thus lighten any mass in which they occur, they promote circulation and would be carried up by rising currents. Circulation is retarded by viscosity, and it appears not improbable that it might be reduced to ineffective stirring movements in the greater depths, where viscosity is very high. At higher levels any local concentrations of radioactive elements would result in foci of heat with melting of bodies large enough to be forced toward the surface and to carry out the heat generators. The suggestion postulates a heterogeneous distribution of the very minute proportion of radioactive substances, somewhat similar to the occurrence of metals in richer or leaner ores. It also assumes barren masses, in which there is no generation of excess heat.

The effect of these hypothetical processes would be to retain heat generators in the central core, to reduce their proportion in a surrounding shell of indeterminate thickness, and to enrich the superficial outer shell in the manner long since recognized by Chamberlin and Holmes.

If in lieu of the molten globe we consider the alternative of the solid one, built up according to the planetesimal hypothesis, the present condition of a molten nucleus and thick, solid shell may be deduced by similar reasoning. It would be expected that the heavier elements, including radium and its relatives, would form the core, and the proportion of radioactive substances, however insignificant, would melt the interior from the center outward to a distance dependent upon the amount of heat generated and the time elapsed. In the surrounding mass a haphazard distribution of radioactive elements in very small total proportion, but with effective concentrations at more or less widely separated foci, would result in local magma bodies, which would be forced toward the surface and would enrich it in heat generators, while impoverishing the substratum.

Thus, by either assumption of the initial state of the globe we may frame an hypothesis of thermal history which would lead up to the present state, but the criteria by which to eliminate either one or the other assumption appear to be lacking.

At this point I may, perhaps, sketch a thought on the margin of this outline of a terrestrial past. It is generally agreed, though not imperatively demonstrated, that the planets probably issued from the sun. In developing a comprehensive panorama of that event Chamberlin considered the sun an active participant. He thought with reason that its eruptive forces must have been strongly stimulated by the tidal pull of the passing star. Jeans and Jeffries did not

take account of those forces. They assumed a film or body of passive gas, part of the sun's atmosphere, yielding initially to the tidal pull in separating from the parent sun and assembling subsequently in response to its own gravitative tendencies. Chamberlin also found it necessary to assemble the sun-dust or planetesimals by gravity. He conceived a process of overtake collision, rebound and repetition of colliding among the particles, by which the dispersive activity would be exhausted and in-fall toward a center of gravity promoted.

Chamberlin's concept of the dynamic conditions of planetary birth is far more complete than that of the astronomers and is not confined by the mathematical fetters imposed upon their way of thinking. Yet even his analysis now seems incomplete in view of the suggestions of modern physics and astronomy regarding the distintegration of atoms and the expansion of the universe. Everything seems to be going to pieces. Energy is dispersing beyond the outermost confines of space. But in space are millions of assemblies of energy, the stars. They are hot and they radiate energy. The thought lies near that energy, darting through the absolute cold of space where heat is powerless by contrast, may encounter conditions favorable to assembly. Possibly the sun-dust had as yet unknown potentialities for gathering to form planets.

From this excursion into the realms of the stars we may return to our little planet and consider the earth beneath our feet. We will not find it lacking in unsolved problems. Take, for instance, the two familiar rocks, granite and basalt: the one is a light-colored, pepper-and-salt looking rock, commonly used in the façades of bank buildings, as an emblem of stability, perhaps. The other is almost black, dense and dull in appearance, and is associated with volcanoes and vast lava fields, like those of Washington and Oregon states. Why are these two great classes of rock different? How did their distinct masses come to form practically the entire crust of the globe?

Granite and basalt are both so-called igneous rocks; that is, they have cooled and crystallized from a molten state. A possible answer to our question is then obvious: they represent the original crust of the once molten sphere, which has cooled down, wrinkled and assumed all the features of Mother Earth. It was a good enough answer so long as we were not embarrassed by too many facts, but if true it required that all the granite and all the basalt should belong to the one rather short age during which the crust formed. We now know that different masses of granite (I am speaking of mountain ranges and large parts of continents) are of very widely separated ages. There are granites nearly two thousand million years old and others less than two hundred million years old. And there are other bodies of granite of various intermediate ages. Each one of them, from the earliest to the latest, rose from within the earth as a melted body and became inlaid in the outer, already existing crust. The same observation holds for the visible masses of basalt—they are of widely different ages. The only masses for which that can not be asserted with knowledge are those which floor the ocean bottoms. Regarding them we can say only that some, like the Hawaiian volcanoes, are very recent in origin and that they have been erupted through much larger areas of similar rock, which are certainly much older. Thus, the old idea that we might discover the oldest rock, a part of the original crust, becomes very improbable, and our first answer has to be put aside.

Among the stock phrases of works on geology is the statement that we know nothing definitely regarding the crust of the earth beyond the depth reached by mining or, in the case of oil wells, by drilling. Once true, that is so no longer. We have seen that elastic waves, earthquake waves, give us information regarding the solidity of the earth to 1,770 miles (2,850 km) below the surface. Those same swift messengers write with a pencil of light the photographic record of the speed with which they have traversed different kinds of rock. As they ascend, they come speeding through basalt, but entering the continental layer of granite they slow down. They record the distance traveled at the slower rate and thus give the thickness of the granite. It is that of a thin scum. A continent, though 3,000 miles (5,000 km) across, is generally not more than 20 miles (30 km) thick. Europe, Asia, Africa, North and South America and Australia are but patches of granite on the underlying shell of basalt that covers the whole globe.

The recognition of this fact again presents problems. What is granite and how did it form patches? If you were to ask a furnace man what slag is he might answer that it is the lighter part of the melt, which floats on the heavier matter in a furnace. The general idea applies to granite. It is lighter than basalt and floats on it. Thus, if we think of the primeval globe as having been molten it is logical to conceive that it was once completely covered by a layer of granite slag that had separated from and floated up on the molten sphere of heavier rock. That is the conception entertained by one school of geologists who imagine a primitive shell, from which later granites may have been derived by remelting. It is not a very well-authenticated notion. The initial assumption of the once molten globe is at best a preferred theory, which is on trial, and the patches of granite represent a complete shell only very inadequately. They cover not more than one third of the

surface. What has become of the other two thirds? "Foundered," is the reply. Since any granite must have floated high and a complete shell must have covered the present ocean basins, that portion which is missing must have sunk. And so, by a line of doubtful postulates, geology is presented with a variety of lost continents, an embarrassing group of mythological Atlantises and Gondwana lands.

We may, perhaps, reach a sounder conclusion if we consult the experience of the furnace man. The ore and fluxes which he melts are dissolved by heat and reunite to form other minerals that are permanent at the higher temperature. The change is an illustration of the law of survival of the fit, which runs through all inorganic as well as the organic world. Then, if given time enough, the newly formed minerals separate and slag rises to float on the metal. If, however, the conditions are not well adjusted, if the process is not sufficiently prolonged or the temperature is too low or too high, the result is not that which is purposed.

The furnace in which granite may separate from some melting parent rock may be conceived to be a part of the globe within some scores or hundreds of miles of the outer surface. It is a mass which has been solid, but contains heating elements and has heated up until the rock is melted. It is a large mass from our point of view, a million cubic miles or several million, but a small one as a part of the earth. It takes a long time to melt, and the process of separation of the various minerals which are present in deep-seated rocks proceeds very gradually as the melt or magma heaves and stirs. The granite minerals soften first, especially in the presence of superheated steam, but basalt when melted is more fluid. The former are the lighter, however, and they must rise, either as individual bubbles or lumpy masses, eventually to gather at the top as a layer of granitic slag. This is not simply an inference based on comparison with familiar furnace practice in smelting ores. The separation has been accomplished by melting basalt in a laboratory crucible. But the processes of nature are far more complex than any we can thus observe, and petrologists find evidences of many different reactions, as we might expect.

In the older geology speculations regarding remelting of any considerable mass within the earth met with a very grave difficulty in seeking the source of heat. Gravity and conduction appeared scarcely competent to concentrate the heat energy required in the local furnace. The discovery of radioactive minerals, capable of generating heat for an indefinite period, suggested a competent source; but progress was impeded for a time by the unnecessary and improbable assumption that the radioactive elements must be uniformly distributed. The alternative assumption that they are irregularly distributed points to the hypothesis that there has been local melting and accords much more naturally with the known occurrences of geologic history.

The basic concept is that the globe had become solid. Whatever its primeval history may have been that solid condition had long been established. But radioactive elements had gradually heated masses of such magnitude that they were from time to time erupted and, intruding into the outer crust, altered and replaced it. We must conceive the eruptions to have comprised many varieties of igneous rock, but the two which occur in notable amounts and cover the globe are basalt and granite. The former constitutes the ocean beds and may be regarded as the foundation upon which the continental granites rest. The presumption is strong that it is the older rock, that eruptions chiefly of basalt had built up the outer surface before continents were born.

A strip of unexplored territory lies between this hypothetical state of a basalt crust and the supposedly later development of the crust of basalt and granite. Two feasible routes appear to lead across it, but either one or other may prove a detour or end in a blind trail. The first considered is indicated by the idea that the present distinction between the two kinds of rocks is a primeval distinction; they have always been separated and their distribution on the present surface reflects some original condition. The other thought is that the separation is the result of some process or processes acting upon a parent rock to differentiate it into these quite distinct groups of minerals. The separation has been accomplished in the laboratory and in the earth. But we are confronted with the question why should melting in the earth's body sometimes produce only basalt and sometimes, though not so abundantly, produce basalt and granite. While experimental research seeks to solve this and similar problems of rock genesis we may speculate.

The process would be one of very gradual melting, first of the more fusible minerals which go to make up granite, and later of the more refractory ones. During the ages of melting, the threads, films and bodies of hot fluid granite should rise through the unmelted portions and gather on top of heavier masses, whether they were melted or not. The process may be visualized as one of differentiation of crystalline minerals by melting and gravity, carried on during a hundred million years or so and resulting in a layer of granite above a body of modified basalt. The layer is relatively thin, since only about 10 per cent. of the parent rock separates out as granite, but it may have been twenty, fifty or more miles thick. A molten mass of these dimensions produces chemical, physical and

mechanical effects upon the surrounding walls and cover which enclose it and tends to rise toward the surface. Unlike the volcanic rocks, granite does not break through, but cools as large subterranean bodies, which are subsequently bared by erosion.

We may thus conceive the formation of the nuclei of continents and the building up of continents themselves by successive eruptions from the depths; but still the question recurs: why not always granite? It is evident that the process which has been suggested is complex and involves several variable conditions. The original composition of the parent rock, the more or less heterogeneous occurrence of several types in layers, fingers or bodies, the rate of heating up and consequently the time available for separation, the distribution of heating elements and the development of convection currents, the greater or less viscosity of the molten body and the total time that might pass before the process was interrupted by upward movement and escape—all these and other variables would need to be appropriately adjusted to produce a given result. It is apparent that the separation of granite, which is a complete stage of the process requiring long time and perhaps several meltings, was a somewhat special case, in contrast to the more common association of conditions favorable to the eruptions of basalt.

Among the effects of modern eruptions is that of the "plateau basalts," as they are called. They are very extensive fields of basaltic lava covering hundreds of thousands of square miles. We may imagine the earlier outflows from the most ancient solid earth to have been of that type and to have resembled the present ocean beds in flatness. The surface built up by such flows would then be comparatively smooth and would have differed from the actual condition in that it would not have been diversified by continents and ocean basins, but would have been covered by a universal ocean.

Evidence of a once universal ocean covering the globe may be found in the curious problem presented by the amount of salt in the sea. Salt is being carried down by rivers, which take it from the land at a rate that can be estimated. Thus, knowing the total amount in the sea, we can calculate how long the rivers have been at work. The calculation involves various guesses, but when all is said and done it seems difficult to allow more than one or two million years for the accumulation of salt in the ocean waters, provided the lands were formerly anything like as extensive as they now are. But two hundred million years is only about one tenth of the known age of some rocks. Hence we are led to infer that the accumulation of salt must have proceeded at a much slower rate, that the lands were for a long time much less extensive and that there was a very long period during which a practically fresh-water ocean covered the entire earth. In a fresh ocean lime-secreting organisms could have developed but scantily, and it may be that the earliest organic limestones will eventually, when their age is determined, tell us when the seas first became somewhat saline and thus indicate the beginnings of continents.

In a universal ocean marine life only could have evolved. Think of the result. We would all have been clams, crabs, sharks or kingfish. But the atomic energies were not to be denied, even though they required hundreds of millions of years to melt and separate the granite slag of which continents consist. Little by little they produced it; mass by mass it was thrust up into the outer crust and lifted to the position where by reason of its lightness it continues to stand out above the heavier basalt that forms the ocean beds. Thus the earth's surface became uneven, the ocean basins were divided and the continents grew to their present size.

The growth of lands was the development of opportunity for evolution of living creatures. Life in the restricted sense may have been born in a crevice in warm, moist soil, during the earliest stages of our planet, and multiplied in the world-wide ocean, evolving from plant cells or bacteria to mollusks or fishes. But the stimulus toward higher organization and mentality was found in the varied climates and aspects of the islands and continents. Variety is not merely the spice of life. It is its incentive.

Let us now sum up the sequence of suggestions that the atomic energies evoke. We start with a solid globe, which contains radioactive elements of great potentiality but in very minute proportion and unequally distributed. Wherever they occur, they generate heat and melting ensues. Any individual molten body tends to rise toward the surface, either forcibly or by melting its way out, and may succeed in rising, bringing the contained radioactive minerals with it. Thus the shell to the depth from which escape is possible becomes impoverished, and the outer crust becomes enriched in heating elements. To them we owe the activity of the external crust. It would seem, however, that the possibility of escape does not extend to the center. A molten mass developing in the central region would become spherical, would be bounded by a spherical contact between molten and solid rock, and pressing equally in all radial directions outward would be held in equilibrium. This seems to be the case. Elastic earthquake waves, which have traversed the 2,000-mile mantle that surrounds the core, are mostly lost in the inelastic core, and the boundary between the shell and the core can be fixed within as short a

distance as 20 miles. So far as we can judge of the state of matter under those extraordinary conditions of temperature and pressure, the core is melted and its diameter of 4,000 miles is that of the sphere which has become molten since the earth acquired sufficient size to retain the melting mass. That was certainly more than two billion years ago. The heating has progressed very slowly. It is possible that the heating elements are exhausted and the molten core is no longer growing. But it seems more probable that the persistent release of atomic forces is continuing and will continue to supply heat and to melt the surrounding shell, with the result that Mother Earth may eventually take her place among the shining stars.

SCIENTIFIC EVENTS

THE WESTERN DIVISION OF THE CONNAUGHT LABORATORIES

IN consequence of an arrangement which has been entered into by the Provincial Board of Health of British Columbia, the University of British Columbia and the University of Toronto, there has been established in the University of British Columbia, as of October 1, a western division of the Connaught Laboratories of the University of Toronto. The undertaking in the first instance is for a period of one year.

Primarily established as a research center, it is hoped that the coordination of activities of the department of bacteriology and preventive medicine of the University of British Columbia with those of the Provincial Board of Health Laboratories of British Columbia and of the Connaught Laboratories will make it possible to extend considerably the fields of usefulness of all three institutions.

Dr. C. E. Dolman has been appointed associate professor and acting head of the department of bacteriology and preventive medicine, and acting head of the department of nursing and health in the University of British Columbia. He has also been appointed director of the Provincial Board of Health Laboratories of British Columbia. He will, furthermore, continue as a member of the staff of Connaught Laboratories as a research member. Dr. R. J. Gibbons, of the staff of Connaught Laboratories, will be associated with Dr. Dolman, seconded for duty in the western division. At the outset the Western Division of the Connaught Laboratories will be provided with quarters in the Science Building of the University of British Columbia.

It is hoped that this experiment in inter-university and provincial health department collaboration will afford excellent opportunities for expansion of activities in the field of preventive medicine in Western Canada, especially in British Columbia.

THE LAWRENCE HOPKINS MEMORIAL EXPERIMENTAL FOREST

THE gift to the Federal Government of a 1500-acre tract of land in northwest Massachusetts by Williams College, Williamstown, Mass., to be known as the Lawrence Hopkins Memorial Experimental Forest, has been announced by the U. S. Department of Agriculture. The tract will be administered by the Forest Service as a branch of its Northeast Forest Experiment Station, and the rehabilitation of New England woodlands and abandoned farm lands which have reverted to forest growth can be studied there.

In a letter accepting the gift, Secretary Wallace wrote to President Tyler Dennett, of Williams College: "Studies on the area will fill an important gap in our program of forest research in the northeast and should be of value in providing a sound technical basis for management and restoration of woodlands and abandoned farm lands over much of New England, whether in private or public ownership."

The Hopkins Forest is in the extreme northwest corner of Massachusetts, adjoining Vermont and New York on its northern and western boundaries. It is just outside the limits of Williamstown, where the college is located. The tract is typical of the abandoned farm land in the region. The principal growth on about 1,000 acres is northern hardwoods, including birch, maple, red oak and white ash in various stages of stocking. The remainder, 500 acres, is old hayfields. The land was formerly the estate of the late Colonel Amos Lawrence Hopkins, who used it largely as a sheep and horse farm. It was donated to Williams College by Mrs. Hopkins.

C. Edward Behre, director of the Northeast Forest Experiment Station, said that investigations of the various problems dealing with the establishment, growth, management and protection of forests, plus the promotion, development and production of desirable forms of wild life in the area would be started. Such investigations are to be carried on particularly in reference to the rehabilitation and best use of such lands. Work of restoring the area to valuable forest land will include replacing poor stock with better tree species.

The forest will also serve as a field laboratory for Williams College, providing an opportunity for honor students to carry on special work in forest botany and allied subjects. The college has made available to the Forest Service for experimental use its own laboratory facilities, library and greenhouses.

Work with the forest will be initiated this winter and a CCC camp will probably be established.

THE REORGANIZATION OF THE DEPARTMENT OF VITAL STATISTICS OF THE U. S. BUREAU OF THE CENSUS

THE *Journal* of the American Medical Association states that with the completion of the primary objective of the department of vital statistics of the U. S. Bureau of the Census, namely, the extension of birth and registration areas which has been its concern for about thirty-five years, a reorganization is now under way to undertake new tasks. In 1933, on the completion of this work with the admission of Texas, the joint advisory committee of the director of the census took steps to explore the various questions and problems involved.

A report of this study points out that "while it is still necessary to work for more complete and accurate recording of the facts as to births and deaths, new and intensive efforts can be devoted now to analytical treatment of the data and to the presentation of more refined results. A better statistical basis for public health work will be laid, and for all studies of population structure and changes."

The appointment of new supervisory personnel in charge of each of three important types of functions within the division is announced, following the recommendations contained in the report. Dr. Halbert L. Dunn, formerly director of the University of Minnesota Hospitals and professor of biometry, University of Minnesota Graduate School of Medicine, Minneapolis, has been placed in charge of the division as chief statistician. He will also have charge of research and analytic developments which are also included in the report's recommendations. Dr. John Collinson, Jr., recently registrar of vital statistics for the state of Maryland and secretary, American Association of State Registration Executives, as assistant chief statistician, will be in immediate charge of the development and perfection of registration and of relations with state health officers and registration officials. A technical assistant to the chief statistician will be appointed to have immediate charge of the classification and coding of causes of death, the development of the joint manual, representation of the division respecting changes in the International List, and relations with medical schools and the medical profession. Forrest E. Linder, Ph.D., who resigned from a position with the Worcester (Mass.) State Hospital, will assist in the development of the program. Six field agents will be appointed, and the districting of the United States for this purpose is proposed. Dr. Timothy F. Murphy, the present chief statistician, has been appointed to take charge of a newly established division of religious statistics, general information and records.

THE UNITED ENGINEERING TRUSTEES

GEORGE L. KNIGHT, vice-president in charge of mechanical operations of the Brooklyn Edison Company, has been elected president of United Engineering Trustees, Inc., joint agency of the four Founder Engineering Societies. Mr. Knight succeeds Harold V. Coes, manager of the industrial department of Ford, Bacon and Davis, New York.

United Engineering Trustees, founded in 1904, administers properties valued at $4,000,000, consisting of the Engineering Societies Building, Engineering Societies Library, and endowment funds which the corporation holds jointly for the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers.

H. G. Moulton, consulting engineer of 20 Pine Street, and Otis E. Hovey, consulting engineer of 71 Broadway, were named vice-presidents. Albert Roberts, of the Minerals Separation North American Corporation, New York, will serve as treasurer. John Arms, general manager of United Engineering Trustees, continues as secretary. The following trustees were chosen: H. P. Charlesworth, assistant chief engineer, American Telephone and Telegraph Company; Mr. Coes; John P. Hogan, Parsons, Klapp, Brinckerhoff and Douglas, New York; J. P. H. Perry, vice-president, Turner Construction Company, New York; A. L. J. Queneau, U. S. Steel Corporation, New York; Walter Rautenstrauch, professor of industrial engineering, Columbia University; D. Robert Yarnall, Yarnall-Waring Company, Chestnut Hill, Pa.; H. R. Woodrow, vice-president, Brooklyn Edison Company.

Mr. Knight, mechanical engineer, has been connected with the Brooklyn Edison Company since 1905, and a vice-president since 1932. From 1902 to 1905 he was with the New York Edison Company. He is a fellow of the American Institute of Electrical Engineers, of which he was vice-president from 1926 to 1928, and a member of the American Society of Mechanical Engineers.

He was a member of the board of United Engineering Trustees from 1926 to 1932, and has been vice-president and chairman of the finance committee during the past two years. He was a director of the Engineering Foundation from 1927 to 1932.

The United Engineering Trustees exists by charter "to advance the engineering arts and sciences in all their branches, to further research in science and engineering, to maintain a free public engineering library, and to advance in any other manner the profession of engineering and the good of mankind." Through the Engineering Foundation, the Library Board, and the

Administrative Department, it aids research in engineering and the sciences, conducts the Engineering Societies Library, the largest strictly engineering library in America, and carries on numerous other activities.

MEETINGS OF GEOLOGISTS IN NEW YORK CITY

THE forty-eighth annual meeting of the Geological Society of America will be held on Thursday, Friday and Saturday, December 26, 27 and 28, in New York City. The headquarters, place of registration, scientific sessions and exhibits will be in the Waldorf-Astoria Hotel, Park Avenue at 50th Street.

Fellows are urged to submit without delay the titles and abstracts of papers which they wish to present at the meeting, so that the Program Committee may arrange to advantage a program of the sessions. No paper will be considered unless the title is accompanied by an abstract suitable for printing in the *Proceedings* of the society.

The address of the retiring president, Dr. Nevin M. Fenneman, professor of geology and geography in the University of Cincinnati, will be delivered on December 26 at 8 o'clock. His subject will be "Cyclic and Non-Cyclic Aspects of Erosion." A smoker will follow the address. The regular dinner of the society will be held on Friday evening, December 27, at 7 o'clock.

In conjunction with the Geological Society the Paleontological Society (Secretary, B. F. Howell, Princeton University) will hold its twenty-seventh annual meeting, and the Mineralogical Society of America (Secretary, Paul F. Kerr, Columbia University, New York City) will hold its sixteenth annual meeting.

Section E of the American Association for the Advancement of Science will meet in St. Louis, Missouri, on December 30 and 31. A joint session with the Seismological Society will be held on December 30. Papers dealing with the geology and geography of the Mississippi Valley will be welcomed for the program of December 31. Full information regarding the meeting may be obtained from the secretary of Section E, Kirtley F. Mather, Harvard University, Cambridge, Mass.

In order to appear in the preliminary programs, abstracts of papers should be in the hands of the various secretaries by November 25.

RECENT DEATHS

PROFESSOR CHARLES LORING JACKSON, who was a member of the faculty of Harvard University for forty-four years until his resignation as professor of chemistry in 1912, died on October 28 at the age of eighty-eight years.

HARRY S. SWARTH, curator of ornithology and mammalogy of the California Academy of Sciences at San Francisco for the past eight years, died suddenly on October 22. He was fifty-seven years old.

DR. ANNA LAURA HINTZE, since 1929 assistant professor of physiology and hygiene at Goucher College, died on October 27 at the age of forty-seven years.

DR. JOHN GOODMAN, professor emeritus of civil and mechanical engineering at the University of Leeds, died on October 28 at the age of seventy-three years.

SCIENTIFIC NOTES AND NEWS

SIMON NEWCOMB, William Penn and Grover Cleveland were elected to the Hall of Fame of New York University in the eighth quinquennial election. The elections have been ratified by the senate of New York University and commemorative tablets and busts to the three men will be placed in the Colonnade at University Heights at ceremonies to take place probably next spring. Sixty-one votes, or a three-fifths majority, were necessary for election. Penn headed the list of candidates with eighty-three votes; Newcomb was second with seventy-eight votes and Cleveland was third with seventy-seven votes. Walter Reed, with fifty-seven votes, and Willard Gibbs, with fifty-five votes, stood next to those elected.

DR. EUGENE H. POOL, professor of clinical surgery at the Cornell Medical Center, was elected president at the San Francisco meeting of the College of Surgeons for the 1936–37 term. Dr. Emile Holman, professor of surgery in Stanford University Hospital, was elected first vice-president, and Dr. George E. Wilson, assistant professor of surgery in the University of Toronto, second vice-president. These officers will be inducted at the end of next year's congress. Officers-elect for the 1935–36 term named at the last congress are: Dr. Donald C. Balfour, of Rochester, Minn., *president;* Dr. Arthur W. Allen, of Boston, *first vice-president,* and Dr. John A. Gunn, of Winnipeg, Canada, *second vice-president.*

THE *British Medical Journal* states that the Leningrad Institute of Post-Graduate Medical Studies has founded a chair in pathology and physiology of the higher nervous activity. It is dedicated to Professor I. P. Pavlov, who presided at the recent International Physiological Congress. The director of studies will be Dr. M. K. Petrova, one of Dr. Pavlov's pupils and collaborators. The purpose of the institute is to en-

able students to study various forms of artificially conditioned neuroses by experimentation on animals, with a view to applying the knowledge to the treatment of human patients.

DR. TANON, professor of hygiene in the Paris Faculty of Medicine and member of the Superior Council of Hygiene of France, has been elected a member of the Academy of Medicine in the section of hygiene. Drs. de Wildeman, of Ghent; Fernandez, of Madrid; Angelescu, of Bucharest, and Presno Bastioni, of Havana, Cuba, have been elected foreign corresponding members.

Nature reports that the following awards by the Royal Aeronautical Society have recently been made: Society's Silver Medal to C. C. Walker and Major F. B. Halford; Simms Gold Medal to Dr. L. Aitchison; Taylor Gold Medal to F. Rodwell Banks, and the Busk Memorial Prize to Dr. H. Roxbee Cox.

DR. A. BAIRD HASTINGS has resigned as professor of biochemistry in the department of medicine of the University of Chicago to accept the Hamilton Kuhn professorship in biological chemistry at the Harvard Medical School. This is the chair held by the late Otto Folin.

THE Bronson professorship of comparative anatomy at Yale University has been filled by the appointment of Associate Professor John S. Nicholas. There has been no appointment to this chair since 1927 when Dr. Ross G. Harrison was named to a Sterling professorship. Professor Nicholas, who received his doctorate at Yale University in 1921, has hitherto had general charge of pre-medical students.

DR. LINWOOD L. LEE, research specialist in land utilization at the New Jersey Experiment Station, has been granted a year's leave of absence to continue as director of the Soil Conservation Service of the U. S. Department of Agriculture.

R. E. BREWER, of the School of Chemistry of the University of Minnesota, has become associate chemical engineer in the Chemical Division of the Bureau of Mines at Pittsburgh, Pa., where his work will be on the physico-chemical properties of coal.

C. F. W. MUESEBECK, entomologist in the Bureau of Entomology, has succeeded Dr. Harold Morrison as chief of the Division of Insect Identification.

DR. I. T. HAIG, chief of the Division of Forest Management at the Northern Rocky Mountain Forest and Range Experiment Station at Missoula, Mont., has been appointed assistant chief of the Division of Silvics in Washington.

DR. G. LOUIS WELLER, JR., clinical instructor in medicine at the School of Medicine of the George Washington University, has been awarded a grant by the Committee on Scientific Research of the American Medical Association for the study of the action of indol upon the hematopoetic tissues of the chick.

DR. HUGH S. CUMMING, U. S. Surgeon General, has returned to the United States after attending the meeting of the Health Committee of the League of Nations in Geneva and the sessions of the Permanent Committee of the International Health Office in Paris.

DR. J. E. WODSEDALEK, professor of zoology at the University of Minnesota, has leave of absence for a year. He has been appointed visiting professor of zoology at the California Institute of Technology, Pasadena, where he is engaged in cytological research in the Wm. G. Kerckhoff Laboratories of the Biological Sciences. Before returning to the University of Minnesota next summer he will spend some time at the Scripps Institution of Oceanography and at the University of Arizona.

WILLIAM G. HASSLER, herpetologist of the American Museum of Natural History, returned on October 29, after seven months passed in studying the life and habits of reptiles and amphibians in Haiti and Dominica. The expedition brought back more than 2,000 preserved specimens, and 430 reptiles and fish were sent back alive.

PROFESSOR BJORN HELLAND-HANSEN, director of the Geophysical Institute at Bergen, Norway, is traveling in the United States. The object of his visit is in part in connection with the committee appointed by the Norwegian government for the promotion of technical industrial research. He plans to study the organization and administration of various foundations, including institutions for international and human relations, and to visit oceanographic and geophysical institutions.

DR. BERTIL HANSTROM, director of the Zoological Institute, University of Lund, Sweden, arrived at the Bass Biological Laboratory on October 23. He has been at the Marine Biological Laboratory at Woods Hole as a stipendiary of the Rockefeller Foundation and has been transferred to Englewood for a month, where he will continue his experimental work with crustaceans.

A GROUP of European health officers, who plan during November to study health problems in leading American cities under the auspices of the League of Nations, arrived in New York on October 31. Members of the delegation include Dr. L. S. Fridericia, professor of hygiene at the University of Copenhagen; Dr. J. Parisot, professor of hygiene at the University of Nancy; Professor R. M. F. Picken, Welsh National School of Medicine, Cardiff; Dr. E. Rietz, chief medical officer of health, Stockholm, and Dr. H. van der

Kaa, chief health officer of the Netherlands. It is planned to visit Baltimore, Knoxville, Cincinnati, Chicago, Albany, Boston, New Haven and New York City.

PROFESSOR EDWIN G. CONKLIN, of Princeton University, will give a lecture on "Scientific and Social Progress" on November 13 before the New York University Chapter of Sigma Xi. The lecture will be given at 8:15 P. M. in the Nichols Chemical Laboratory at University Heights.

DR. MAURICE C. HALL, chief of the Zoological Division of the Bureau of Animal Industry, spoke before the Sigma Xi Club of Oregon State College on October 8 on "What is Scientific Research?" Dr. H. B. Lewis, professor of biological chemistry in the Medical School and director of the College of Pharmacy at the University of Michigan, spoke on October 19. His subject was "Vitamines and Hormones."

DR. WILLIAM D. MACMILLAN, professor of astronomy at the University of Chicago, on October 29 gave a public lecture entitled "Dynamical Astronomy" in the series of lectures now being given at the university on "The History of Science."

DR. A. B. STOUT, director of the laboratories of the New York Botanical Garden, gave a lecture on November 7 before the Lancaster Branch of the American Association for the Advancement of Science on "Sterilities in Flowering Plants."

THE first lecture in the Smith-Reed-Russell Series for this year at the George Washington University School of Medicine was given before the student body, members of the faculty and invited guests on October 24. The guest speaker for the occasion was Surgeon General Charles R. Reynolds, Medical Corps, U. S. Army. The subject of his address was "The Medical Corps of the United States Army."

DR. BERNARDO A. HOUSSAY, professor of physiology and director of the Institute of Physiology of the University of Buenos Aires, will give at Harvard University on November 22, 25 and 27 the 1935 Edward K. Dunham Lectures for the Promotion of the Medical Sciences. His subject will be "Recent Studies on the Functions of the Hypophysis."

THE one hundredth anniversary of Thomas Nuttall's expedition to the Pacific coast in 1834, 1835 and 1836 was observed by exercises in the open air at the Jepson Laurel, Spring Valley Lakes, California, on October 20. Papers were read by representatives of various organizations: Cornelia C. Pringle, Cooper Club, "Pica Nuttallii, its Geographic Range and Habits"; Professor E. Fritz, Division of Forestry, University of California, "Cornus Nuttallii, its Place in the Forest"; Dr. E. R. Hall, California Museum of Vertebrate Zoology, "Thomas Nuttall as a Mammalogist and Ornithologist"; Dr. W. L. Jepson, California Botanical Society, "The Trail of Nuttall Across the Continent in 1834"; Frank L. Dodd, Berkeley Teachers College, "The Botanist as an Idealist in the World as We Find it"; Professor W. W. Mackie, University of California, acted as master of the day.

A SYMPOSIUM entitled "Ultra-Violet Light at Work for Better Human Health" will be held at 9 P. M. on Thursday, November 14, under the auspices of the American Institute at the American Museum of Natural History, New York City. Exhibits and demonstrations will be made by the National Carbon Company; Standard Brands, Inc.; Hanovia Chemical and Manufacturing Company; Westinghouse Electric and Manufacturing Company; The R.U.V. Engineering Corporation, and others. Exhibits will include apparatus for producing irradiated vitamin D milk, irradiated yeast, viosterol, and other products, ultraviolet radiation meters, etc. Dr. William H. Park, Bureau of Laboratories, of the Department of Health, New York, will preside at the symposium, at which the individual subjects and speakers are as follows: "Ultra-Violet Radiation," Dr. M. J. Dorcas, advisory engineer, National Carbon Company; "Irradiated Milk," Dr. G. C. Supplee, director of research, Dry Milk Company; "Irradiated Pharmaceuticals," Dr. Carl Nielsen, director of nutritional research, Abbott Laboratories, and "Irradiated Cholesterol," Dr. James E. Waddell, director, Biological Laboratory, E. I. du Pont de Nemours and Company.

THE *Journal* of the American Medical Association states that an anonymous contribution has made possible the establishment of a foundation for dental research in the Chicago College of Dental Surgery, the dental division of Loyola University, which will have available annually $25,000 as a minimum. The major part of the work will be carried on in the laboratories of the dental school, while another part will be undertaken at the John McCormick Institute for Infectious Diseases. Some of the problems to be investigated will be a study of the bacteriology and histopathology of dental caries and the diseases that involve the supporting structures of the teeth as well as their effects on general health.

A NEW building to cost approximately $400,000 will be erected by New York University at University Avenue and 180th Street, the Bronx, to house part of the institution's College of Engineering. It will be erected in cooperation with the Reconstruction Finance Corporation. The present plant will be turned over to experimental purposes. On the first floor will be material-testing laboratories and the hydraulic laboratories, while on the second floor there will be lecture halls and offices. The third floor will house the univer-

sity's meteorological laboratories which are now charting air currents on the outdoor campus.

THE trustees of the Rockefeller Foundation have made a conditional offer of £60,000 to aid the National Hospital, London, a leading center for the treatment and study of nervous diseases. The money is to defray the cost of new buildings and equipment on the condition that the balance required, estimated at £120,000, is raised within two years. If the condition is fulfilled, the trustees will give a further £60,000 toward an endowment for research.

THE London *Times* reports that the Danish government's scientific expedition ship *Dana* sank recently in the North Sea sixty miles west of Ringkjöbing, Jutland, after a collision in thick fog with the German trawler *Pickhuben*. The leader, Dr. Vedel Taaning, and the crew, in all twenty-two men, were saved by the *Pickhuben* and brought to Esbjerg. The *Dana* was the ship used by the late Professor Johannes Schmidt, as director of the physiological department of the Carlsberg Laboratorium, on oceanographic expeditions to trace the migration of eels. Oceanic life was studied at the greatest depths with special echo-sounding gear, which is now lost, together with the results of expeditions during the last three years.

DISCUSSION

THE BORN THEORY OF THE ELECTRON

THE theory of the electron as formulated by Dirac has been especially successful in its application to atomic physics. However, when it comes to a treatment of phenomena in which the scale of the quantities involved in the calculations are of a lower order of magnitude than those considered in atomic physics, then discrepancies occur. This is readily understood when it is remembered that the Dirac equations are founded on the concept of a point electron. Born[1] has attempted to remedy the situation by replacing the concept at the basis of the classical electron of Lorentz by another set of fundamental ideas. As yet there is much discussion of the validity of his hypotheses. Perhaps the best test of any theory is the comparison of its predictions with experiment. In this note we shall give the results of the investigation of one of the properties of the Born electron. Before we discuss this we shall review briefly some of the other properties of the theory as they have a bearing on the problem.

(a) The Born electron has a finite mass. This is a property which any theory of the electron must guarantee.

(b) The theory requires that the effective electric intensity for electric waves of wave-length less than the radius of the electron be an average of the true electric intensity over the electron. In calculating problems in quantum mechanics involving electric waves of this character, the theory supposes that the equations of Dirac be used with the effective electric intensity substituted for the true intensity.

(c) This is the problem where the deviations from the classical theory are the most striking. The Born electron has properties which correspond in the theory of ponderable media to a dielectric constant and magnetic susceptibility. The field equations are non-linear. This results in the effective electric force acting on an electron in an intense electric and magnetic field being proportional to the sum of two terms: in the one, the electric intensity is the predominating term; in the other, the magnetic intensity. As a consequence of this, the effective electric force acting on an electron in a strong electric and magnetic field is greater than the force arising from the effect of the electric intensity alone. A situation where these considerations are important is in the problem of the production of photons by a high energy electron impinging on a nucleus. In the solution of this problem one method is to choose a system of axes in which the electron is at rest and then to consider the field of the nucleus acting on the electron as a system of electric waves. The scattering of the waves by the electron has for an observer at rest with respect to the nucleus the effect of the emission of radiation. According to this theory, the probability of the emission of two photons simultaneously is to the emission of one photon as the ratio of $2\pi e^2$ to hc where e is the charge on the electron, h Planck's constant and c the velocity of light. This ratio is equal to 1/137. Hence the chance of two photons being emitted simultaneously is negligible. On the Born theory, however, the increase in the effective electric intensity in those regions where the electric and magnetic fields are strong results in an increase of this ratio to $2\pi e^2\varepsilon/hc$ where ε is greater than one. If Z is the atomic number of the nucleus struck by an electron of kinetic energy ξ as measured in units of mc^2 then the production of small showers, *i.e.*, the simultaneous emission of two or more photons at a collision, should occur when the following relation is satisfied: $2 \times 10^3 \leq Z\xi \leq 2 \times 10^4$. This relation requires that the showers should be softer the heavier the nucleus involved in the collision. Such a theory also would require a revision of the theory of the hyperfine structure of spectral lines. We merely mention these illustrations to show where we may

[1] M. Born, *Proc. Roy. Soc.*, A 143: 410, 1934; M. Born and Infeld, *Proc. Roy. Soc.*, A 144: 425, 1934.

expect alterations in the current theory if a non-linear theory is correct.

ARTHUR BRAMLEY

PRINCETON UNIVERSITY

THE QUESTION OF WILDLIFE DESTRUCTION BY THE AUTOMOBILE

IN connection with the steady increase in the volume of automobile traffic in recent years considerable attention has been given to the killing of animals straying on or deliberately crossing the highways in search of food, water or other environmental requirements. In previous issues of SCIENCE observations on the extent of such destruction have been reported. Stoner,[1] 1925, observed 225 dead animals on the highway in Iowa during a three-day trip of 632 miles. Davis,[2] 1934, reported the destruction of 179 animals in two days on a stretch of 500 miles enroute from Iowa to Amherst, Massachusetts. These two observations each indicate an average of .36 dead animals per mile. This appears to be an alarming rate of destruction. Nor is the bulk of this killing confined to cats, dogs and fowls. Stoner lists 28 species, and instances of killing such large animals as a deer are known.

In the light of these facts an observation made on a 1,500-mile trip from Chicago, Illinois, to Woods Hole, Massachusetts, from June 26 to July 1, 1935, and on a return trip of 1,050 miles from Woods Hole to Cincinnati, Ohio, from September 1 to 4, 1935, appears to be particularly interesting. The following dead animals[3] were seen on or at the side of the road.

1. Cat (*Felis domestica*)	3
2. Chipmunk (*Tamias striatus*)	1
3. Dog (*Canis familiaris*)	5
4. Muskrat (*Ondatra zibethica*)	1
5. Rabbit (*Sylvilagus floridanus*)	3
6. Rat (*Rattus norvegicus*)	2
7. Skunk (*Mephitis nigra*)	8
8. Squirrel (*Sciurus carolinensis*)	1
9. Squirrel (*Sciurus niger*)	1
10. Downy woodpecker (*Dryobates pubescens medianus*)	1
11. Flicker (*Colaptes auratus luteus*)	1
12. Fowl (*Gallus domesticus*)	3
13. Robin (*Planesticus migratorius*)	3
14. Sparrow (*Passer domesticus*)	1
15. Garter snake (*Thamnophis sirtalis*)	3
16. Turtle (*Chelydra serpentina*)	2
17. Turtle (*Terrapene carolina*)	16
18. Unidentified	6
Total	61

[1] Dayton Stoner, SCIENCE, 61: 56–58.
[2] Wm. H. Davis, SCIENCE, 79: 504–505.
[3] Species according to H. S. Pratt, "Vertebrate Animals of the United States," Blakiston, 1935, and E. H. Forbush, "Birds of Massachusetts and Other New England States," Mass. Dept. Agric., 1925–29.

This total of 61 dead animals in 2,550 miles is an average destruction of .024 animals per mile, which is only one fifteenth the rate of killing reported by Stoner and Davis. On the basis that no carcass was more than 48 hours old when observed, the calculated rates of killing in the two cases, .36 and .024, indicate death rates of .18 and .012 animals per mile per day. Applying these death rates to the 750,000 miles[4] of hard-surfaced and improved roads in the United States produces an estimated killing of 135,000 animals per day, according to the Stoner and Davis figures, as compared with 9,000 per day on the basis of the present figures. Considering the great mileage of slightly traveled roads included in the total mileage and the close relation of speed and volume of traffic to rate of killing, it is believed that the lower rate of killing is too high for a daily nation-wide rate. Even at the higher rate, the killing, calculated for a corresponding period of time, amounts to only four fifths of the estimated annual (1935) slaughter of ducks alone, five to six million,[5] in a hunting season of thirty days.

From the author's point of view, *i.e.*, destruction of wildlife, the eleven cats, dogs and fowls listed are of no significance but are included for the sake of comparison with other such lists. Excluding these eleven animals from the calculations the observed death rate per mile per day for wildlife only is .0098, a rate which would produce an estimated daily destruction in the entire United States of 7,350 animals.

It is evident from the present observation that the automobile is not uniformly so great a menace to wild life as the death rate of .18 animals per mile per day, suggested by previous observations, would indicate. The Davis records of one dead rabbit per mile for 100 miles in Ohio or 200 dead animals in two miles of woodland road must be exceptional cases of destruction, at least as unusual as some may consider the present observation of only 61 dead in 2,550 miles. It is further indicated that the rate of killing may vary greatly from year to year, and also within a single season, probably in relation to marked departures from the normal temperature, humidity and precipitation, or in relation to seasonal activities of the animals. Hot dry summers, such as the seasons of 1933 and 1934, produce a definite alteration and limitation of the usual normal habitats and result in restless, exploratory activity on the part of the local fauna, bringing the animals into increased contact with the motor traffic on the highways. This movement, and accordingly the amount of killing, would be much less under the normal temperate conditions prevailing in the region surveyed

[4] U. S. Dept. of Agric., Bureau of Public Roads, Table M-5 (1930) and M-4 (1933).
[5] *Time*, August 12, 1935.

during the summer of 1935. Seasonal movements of some animals, in connection with breeding or hibernation, may result in their greater destruction temporarily, but such killing is no basis for the estimation of a continuous daily rate of killing. Finally, let no sweeping conclusions as to the destructiveness of the automobile in respect to wildlife be drawn from such limited and variable observations as have been described here. The problem is in need of a systematic statistical survey covering several seasons and various localities.

W. A. DREYER

UNIVERSITY OF CINCINNATI

IS A PACEMAKER INVOLVED IN SYNCHRONOUS FLASHING OF FIREFLIES?

ONE hesitates to add another discussion to the long series already published on the fascinating problem of synchronous flashing of fireflies. The existence of this phenomenon in the tropical Orient is well established, and good descriptions of it have appeared in this journal[1, 2] and elsewhere.[3] It is so easily observable in Siam that some of the efforts to explain it away are "more remarkable than the phenomenon itself."[2] However, my own observations suggest that the mechanism which maintains the synchrony involves a pacemaker, with stimulation through the light, a view not altogether in accord with previously published statements, but in agreement with a recent general interpretation of such phenomena.[4]

The phenomenon, during certain seasons,[1] may be readily observed from a boat in the Chao P'ya River between Bangkok and the sea. At some distance from the shore one may observe flashing in mangrove trees extending (at my estimate) for a quarter of a mile or more up and down the river. Although all the insects in these trees are flashing at the same frequency, and seem at first glance to be flashing in perfect unison, it has been my observation that each flash appears as a pulse of light that moves with great rapidity across the field of vision from one side to the other. In other words, in a long stretch of shore one may detect a slight *difference in time* of flashing (though *not in frequency*) between the insects that are some distance apart. My wife and others with me have verified this observation. Perhaps it could not be made satisfactorily in a small area, because, in spite of the high frequency (over ninety flashes per minute), all the trees visible at one time are darkened between consecutive flashes. In other words, if, as seems likely from this observation, a pacemaker stimulates the synchrony, the latent period of response to the stimulus by the individual insects is extremely short.

Morrison[1] pointed out two facts that are in accord with this interpretation, (1) the synchronism of the flashing may be inhibited by "exposing them [the fireflies] to a bright light for about a minute," and (2) "when the light is turned off, the synchronism returns, having its origin, apparently, in some individual or group generally located in the central part of the tree. From this group, then, the synchronism extends over the entire tree in an irregular wave until all of the insects are flashing in unison." However, he did not believe that the synchrony once established involved a pacemaker: "Furthermore, any follow-the-leader action on the part of the insects would result in a wave of light passing over the tree and originating from a definite point, a fact which is not the case once the synchronism has begun." What I have observed is this particular bit of crucial evidence—not a wave of light passing over a single tree, however, but a wave of light passing over a long row of trees.

Of some interest in connection with the suggestion of a permanent pacemaker are the experiments described by Hess.[5] In one of the rare observations of synchronous flashing of American species, in this case in a valley near Ithaca, New York, he found that he could initiate synchronous flashing by means of a pocket flashlight and even cause the insects to adopt a somewhat higher frequency.

It is not difficult to conceive of an internal mechanism which would make possible such a rhythmic behavior in a single individual. It might be some kind of recovery mechanism, as was early suggested.[6] A greater problem lies in the explanation of a synchrony which involves so many thousands of individuals; although, of course, a recovery mechanism may very well have a part in determining the frequency. A mechanism which is responsible for rhythmic behavior does not explain the synchronism of rhythmic behavior in different individuals. That seems to require an integrative factor. My own suggestion is that a pacemaker is a continuous as well as an initiating factor. In the absence of a pacemaker mechanism we should be forced to postulate the existence of an accurate physiological chronometer, a mechanism to most of us quite inconceivable.

GORDON ALEXANDER

UNIVERSITY OF COLORADO

THE FIRST SCHOOL OF CHEMISTRY

I HAVE just been reading Thomas T. Read's short article[1] on the First School of Chemistry, in which he

[1] T. F. Morrison, SCIENCE, 69: 400–401, 1929.
[2] Hugh M. Smith, SCIENCE, 82: 151–152, 1935.
[3] T. F. Morrison, *Journal of the Siam Society, Natural History Supplement*, 7: 71–81, 1927.
[4] W. C. Allee, "Animal Aggregations," pp. 88–96. Chicago, 1931.
[5] W. N. Hess, *Biological Bulletin*, 38: 39–77, 1920.
[6] K. G. Blair, *Nature*, 96:411–415, 1915.
[1] SCIENCE, October 18, 1935, page 371.

mentions the School of Chemistry established at Columbia in 1862.

A somewhat similar case is that of the School of Applied Chemistry at Yale, which was started in 1847 by Professors Benjamin Silliman, Jr., and John P. Norton. The school later became the Scientific School and in recognition of the gifts of Joseph Sheffield became the Sheffield Scientific School in 1861. Up to 1852 the Scientific School was a School of Applied Chemistry; from that date other scientific subjects were introduced.

PHILIP E. BROWNING
YALE UNIVERSITY

SCIENTIFIC BOOKS

THE ALLIGATOR

The Alligator's Life History. By E. A. McILHENNY. 117 pp., 18 illustrations from photographs. The Christopher Publishing House, Boston, 1935.

THIS little book, though written in popular vein by a well-known business man, is a really valuable contribution to the ecology of our largest native reptile. It is doubtful if any other educated man has ever lived so long and intimately with *Alligator mississippiensis* as has Mr. McIlhenny, who has spent his entire life at the family estate on Avery Island, Louisiana, and has studied the alligator from early boyhood days. A considerable number of facts brought out in this interesting account, so far as the reviewer is aware, are here made known for the first time.

He has studied the food habits of the alligator, both by seeing the animals caught and by an extensive study of stomach contents. He saw a 3-year-old cow seized and drowned by a 12-foot 'gator and a "large sized" deer by a 9-foot 'gator. He saw a 3½-foot alligator eat an entire brood of eight young duck as they swam less than 200 feet across a lagoon. The stomach of a male alligator, 10 feet, 1 inch long, contained 11 herons, 4 garfish and 4 turtles. Muskrats are the chief food of alligators in land-locked ponds. Water snakes and gars are frequently eaten, so that where alligators are numerous these forms are scarce; and where gars are numerous, game fish are apt to be scarce.

In studying the rate of growth he toe-marked many young animals, which were caught and measured at intervals, thus getting data on growth under absolutely natural conditions.

The largest alligator of which he knew the actual measurement was 19 feet, 2 inches long. The females seldom if ever exceed 9 feet in length. A 15-foot alligator is 30 to 40 years old.

An individual alligator may occupy the same den for 30 years. This den may be 60 feet long and have more than one entrance. The author has watched the animal excavating its den in the bank of a stream. He has also watched, from a blind, a female build her nest and lay the eggs in it, at a rate of about one egg every nine seconds. He says the female crawls over her nest once or twice a day and moistens it by voiding urine over it.

By repeated observations he determined that the normal period of incubation is 63 days, with only 2 or 3 days variation either way. Daily maximum and minimum temperature readings were taken of the interior of the nest and of the outside temperature. The highest maximum recorded for a nest was 102°; the lowest minimum was 88°.

It is commonly said that the mother pays no attention to her young after liberating them from the nest, but the author states that the young remain with their mother until the onset of the breeding season of the spring following their birth; and he has, on several occasions, seen the mother crush an animal in her jaws and hold it at the surface of the water for her young to devour.

The author is evidently skeptical of the reviewer's statement that embryos are found in fresh-laid or even in uterine eggs, but says if such be true it is an abnormal condition. Of the hundreds of alligators and caiman eggs opened by the reviewer, practically all those that were fertile contained embryos in early stages of development. The author is of the opinion that the bellow or roar of the alligator, always by the male, which may be heard on a quiet night for a distance of three miles, is a challenge rather than a call to the other sex.

The alligator has already been exterminated over a large part of its original habitat, but it has been shown that it will increase rapidly if given protection against hunters. For example, it was protected on various southern refuges and in four years increased so rapidly that the muskrat hunters complained, and 100 hunting permits were issued which resulted in the destruction of between 88,000 and 89,000 alligators in the year 1916.

Three years ago Mr. McIlhenny set aside about 5,000 acres of suitable land where no alligators were to be killed; already a large increase in young animals has been noticed.

Mr. McIlhenny has never heard of an authentic case of a human death by an alligator.

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AERONIZATION IN MEDICINE

Aeronisation in Medicine. Edited by Professor A. L. TCHIJEVSKY and DR. G. A. LAPIDUS. Vol. III, Transactions of the Central Laboratory for Scientific Research of Ionification. Publishing House "Kommuna," Voronej, USSR. 1934.

IN the issue of SCIENCE for May 31 Professor Alexis L. Romanoff, of Cornell University, had a brief review of "Problems of Ionization" published in Moscow. Since several inquiries received by Professor Romanoff have been referred to me, as I had the privilege personally to know Professor Tchijevsky, and to visit him in Moscow, I believe the readers of SCIENCE will be glad to have additional information about the Central Laboratory for Scientific Research of Ionification.

A few days ago the writer had the pleasure of receiving a letter from Professor Tchijevsky, and also a copy of Volume III, entitled "Aeronisation in Medicine." This volume contains fifty-eight articles on aeronization in medicine, contributed not only by Dr. Tchijevsky and his associates in the Central Laboratory, but a number of experimenters in other medical institutions in Moscow, Voronej and other cities. Among the subjects treated are: Application of aeroions in physiotherapy; aeroionotherapy of wounds; influence of aeronization on the tubercular process in rabbits. There are also four articles on treatment of tubercular patients with inonized air, the reactive changes in the internal organs, and in the nervous system by aeronization, influence of aeronization on the growing organisms, also on the polyavitaminosic pigeons, etc. There are several chapters on apparatus for the production of pharmacological aeroions and for their count, method of producing highly ionized water, steam, medicinal solution, highly concentrated heavy ions in medical solutions produced by electrostatic pulverization. Several chapters are also devoted to aeronization of shops and factories. The work on ionization by Professor Dessauer and other European scientific men is discussed.

Dr. Tchijevsky writes that his apparatus for ionization is different from that used elsewhere, and that he has the invention patented in USSR.

Volumes II and IV are now in press. The tables of contents of all volumes are announced. Volume III has an English table of contents and a fifteen-page résumé in French by Dr. Tchijevsky.

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NEW YORK, N. Y.

SPECIAL ARTICLES

BACTERIAL CONTENT OF THE AIR AT HIGH ALTITUDES

NUMEROUS investigations of the upper air for the presence of bacteria and fungi have been made by several observers. Procter in Boston has made about forty flights, one up to the height of 20,600 feet, and has taken cultures from the air under diverse conditions. Meier, in Washington, in conjunction with the Naval Department, has made extensive studies but has confined himself mainly to the search for fungi. In the recent flight over the Atlantic by Lindbergh, glass plates covered with an adhesive material were exposed at different heights and under diverse conditions over land and water in order to catch the spores of fungi. These plates were studied by Meier.

On October 3, 1934, I made a flight to the height of 20,000 feet and exposed blood agar in Petri dishes at every 1,000 feet. Technical difficulties prevent the procuring of accurate data.

Prior to my recent flight the highest altitude at which this work had been done was 20,600 feet.

With the permission of General MacArthur, of the U. S. Army, a recently constructed bombing plane at the Glenn Martin Plant was put at my disposal for a flight above 20,000 feet.

This plane was selected more particularly on account of the compartment provided for the machine gunner which formed a kind of a nose of the plane and the farthest point forward. The propellers and the other sections of the plane were behind this prominence. This compartment was encased in glass and aluminum framework and had a slit in the front through which the hands could be projected and the plates exposed. In this manner one could be certain that the air striking the plates was free from contamination from any other part of the plane.

Blood agar in Petri dishes and a special medium in other Petri dishes for fungi were used. These dishes were sterile on the outside and were wrapped in sterile gauze and sterile paper. They were packed in sterile containers and placed in a convenient location in the plane. After exposure the plates were again wrapped in the material which had been around them and put in a second sterile container.

I was alone in the compartment. The pilot, Captain Polk, occupied the pilot's seat and had charge of the plane. I had on a very thick flying suit and was definitely restricted in my movements.

The technique was as follows: The plates were taken out of their container and unwrapped. Sterile rubber

gloves were then put on and each plate was held with both hands outside the opening; the cover was then raised and the medium exposed to the wind for a half to one minute. The cover was then replaced and the dish was wrapped in gauze and paper and stored in the container. Cultures were taken in this manner every 1,000 feet, and in two instances where there was a fault in the technique a second culture was taken.

The wind coming in contact with the plates and with my hands had a velocity of 150 miles an hour. About 7,000 cubic feet of air passed over the plate in one minute. The calculated temperature at 28,500 feet was 34° F. below zero.

My hands soon became so numb and stiff that I could not carry out the technique as I had planned it. There were faults in opening and closing the plates and it was found impossible to protrude the hands far enough outside or to hold the plate longer than half a minute. It must be acknowledged that due to these errors there may have occurred possible contaminations from the inside of the plane. Then, too, it was found that the medium in several of the plates was completely frozen when I got back to the laboratory.

The plates were put in incubators and were examined very carefully during the next ninety-six hours by a competent bacteriologist.

The report was as follows:

A plate exposed	at 19,000	feet	was negative
" " "	" 20,000	"	" "
" " "	" 21,000	"	" "
" " "	" 22,000	"	" "
" " "	" 23,000	"	" "
" " "	" 24,000	"	showed one colony of *Staphylococcus albus* (surely a contamination)
" second plate	" 24,400	"	was negative
" plate exposed	" 25,000	"	" "
" " "	" 26,000	"	showed one colony of *Staphylococcus albus* (surely a contamination)
" second plate	" 26,300	"	was negative
" plate exposed	" 27,000	"	" "
" " "	" 28,000	"	" "

In two plates, one at 24,000 feet and the other at 26,000 feet, the colonies of staphylococci found were most probably due to a contamination, because in each one of them definite faults had been observed and a second plate had been exposed.

The work was not done with sufficient accuracy to claim the establishment of any new facts, but it suggests that the atmosphere from 20,000 feet to 28,500 feet is sterile.

In this flight we attained the highest altitude at which cultures had ever been taken and in this sense it is a record.

The plates for fungi were not exposed.

The flight demonstrated the impossibility of carrying out the technique as planned and showed the necessity of having some kind of a mechanical device for opening, exposing and closing the plates. I am now trying to devise such an apparatus.

It may be of interest to say that I began the use of oxygen at 21,000 feet and did not experience any embarrassment of respiration, but my hands suffered quite severely from the cold. My right index finger was frost-bitten and my right hand did not regain its normal feeling for several hours after I came down. The finger remained numb for about one week.

The pilot and I used a container holding five liters of liquid oxygen. One tube went to his compartment and a second came to mine. We were entirely separated in the plane and I was unable to make any signal to him. This was a marked disadvantage and a matter of considerable mental discomfort.

I wish to express my sincere appreciation to General MacArthur for the use of the plane and to Captain Polk for his hearty cooperation and for his high degree of skill as an aviator.

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ON THE NATURE OF FILTERABLE VIRUSES[1]

THE defining characters of filterable viruses appear to be ultramicroscopic size and obligate parasitism. They are the smallest units showing the reproductive property considered typical of life. While it is recognized that obligate parasitism does not necessitate their extreme smallness, there is apparently something related to the ultramicroscopic size of filterable viruses that obligates them to a parasitic existence. From information at hand we must conclude that the ultraviruses demand direct association with living cells to display the most characteristic property of life, that of reproduction.

It is of great significance that modern intense studies of microbiology have failed to discover any evidence of the existence of free-living microbes of ultramicroscopic size. In any case, where changes occur in an organic or inorganic solution that indicate definitely the presence of living microbes, they can always be demonstrated by direct microscopic examination. Even more critical experience has been gained by the use of bacteria-proof filters. Whenever filtered solutions show biological change indicative of microbic growth, visible microbes appear always to be present. There are, of course, bacteria that will regularly pass the usual bacteria-proof filters. Cultures of certain sulfur bacteria which grow on inorganic

[1] Presented before the North Central Branch of the Society of American Bacteriologists, June 26, 1935, meeting with the American Association for the Advancement of Science at Minneapolis.

sulfur in water are extremely minute and the smallest cells in such a culture are apparently just ultramicroscopic and will regularly pass a Berkefeld filter. However, the growth obtained from such a filtrate contains the usual visible bacterial cells. While it may be that a whole world of free-living ultramicrobes remains to be discovered, this now appears very improbable.

A conviction that there are no free-living ultramicroscopic microorganisms brings us at once face to face with the curious sharp limitations of the size of free-living forms at a dimension that also represents the limits of microscopic visibility. If we survey generally the magnitudes of living forms, we see that those of extremely large size are relatively few in number and kinds. With a decrease in magnitude there is an increase in both kinds and numbers. In the microscopic world kinds become difficult to distinguish and individual numbers become enormous. There is a sudden limitation in numbers just above the smallest visible magnitude. Beyond that size occur only those curious parasitic forms which we designate as filterable viruses. It appears of great significance that all life smaller than a certain size is obligately dependent upon life of greater magnitude than that size. We could express that limiting dimension in terms of any unit we please, but as long as it corresponds to the range of the visible spectrum, it may be of some significance to consider it related directly to the wavelength of light.

It is the apparent absence of free-living ultramicrobes on this earth that indicates a microbic origin of filterable viruses. Our knowledge of the relationship of visible parasites establishes that parasitic forms are derived from free-living forms. We must accept also that ultramicroscopic parasites have also originated from independent forms. The ultraviruses can be adaptives from only two possible sources. First, they may be surviving parasitic forms developed from free-living ultramicrobes formerly inhabiting the earth and now extinct. Secondly, they may be parasitic forms of life developing by retrograde evolution from visible microbes similar to the visible forms now existent. The assumption of a present or past world of free-living ultramicrobes is pure conjecture, with no single fact to substantiate the assumption. A theory of microbic origin of filterable viruses by retrograde evolution from visible microbes naturally follows our knowledge of evolution in the visible world.

The primary characteristic of retrograde evolution under parasitism is a loss of function and associated substance. A common example of this is the tapeworm which, adapting itself to life in the gastrointestinal tract, has lost all vestiges of a functional or anatomical digestive system of its own. As far as its adult form and physiology are concerned, it is mainly a collection of vestiges with an exaggerated reproductive ability. It is an obligate parasite because it has become an incomplete form of life.

The obligate features of parasitism by microorganisms likewise represent a loss of function for which the parasite becomes dependent upon the host. Many pathogenic microorganisms are obviously dependent for growth on substances existent in their hosts, but generally the nature of these compounds is unknown. *Pasteurella tularensis* of McCoy is a clear-cut example of a known loss of function, which in this case concerns the metabolism of cystine. This organism can lead a saprophytic existence, independent of a living host only when cystine is made available. It does not take any stretch of the imagination to visualize this retrograde process extending to a considerable loss of function and finally resulting in a loss of all mechanism formerly concerned with this function.

The development of parasitism depends primarily upon conformity of the parasite to the host. The parasite must propagate its kind before it destroys its host. This conformity becomes very great for parasitism within tissue and exceedingly so for intracellular parasitization. With parasitism established comes the opportunity for acceptance of host functions by the parasite. For an intestinal parasite this would be limited largely to digestive functions. While adaptation to a parasitic existence within tissue in the intercellular spaces would require great conformity, the opportunity for function acceptance would be limited. Once, however, a microorganism has developed the conformity and ability for intracellular parasitism, the opportunity for function acceptance becomes extremely great. The intracellular microbe is surrounded by protoplasm functioning basically in a manner similar to its own protoplasm. The opportunity is afforded to depend upon the host protoplasm for certain metabolic functions and these the parasite can accept. The specific location of intracellular microbes either within the protoplasm or within the nucleus as seen for members of the Rickettsia group is visible evidence of the same intracellular selection and adaptation indicated by physiological deficiencies.

As seen for gross parasites, loss of function is followed by loss of structure and substance. This is apparently true also for parasites composed of a single cell. That the protoplasm of microbes has sufficient plasticity for specialization is shown by the organelles of protozoa. It follows that the capacity is also inherent for retrograde simplification. There can be little doubt that loss of function by an intracellular microbe is followed by loss of structure and substance. This simplification and decrease in size is in itself a tremendous advantage to intracellular parasitism. The opportunity for such simplification is so

great and the result so much to the advantage of the intracellular microbe that the process must proceed to the development of a highly incomplete form of parasitic life obligately dependent upon the host cell for many of its vital functions.

Such partial forms of life could develop to various degrees of simplification. It is conceivable that the retrograde process could proceed until only those molecules concerned with reproduction remained as the parasitic unit. Such a residuum could be as small as a single colloidal molecule and would correspond to the smallest of the viruses. Such a virus would be a functionally complete unit of life only when immersed in living protoplasm. There it would complement its own limited vital processes with those of the surrounding protoplasm. While the host cell continued its metabolic activities, the virus would be a living functionary individual. This concept corresponds with the general observations that filterable viruses reproduce only when in association with living cells.

The great diversity observed for the group of filterable viruses is readily understood from this viewpoint. We should expect as great a diversity as among the microorganisms from which the viruses have been derived. The extensive intracellular adaptations seen for the protozoa, especially among the Sporozoa, indicate that many of the filterable viruses may have developed from these forms. The true bacteria with their many pathogenic races offer points of origin for many viruses of quite different properties.

While this concept of filterable viruses defines them as primarily simplified fragments of living protoplasm, it does not preclude the concomitant development of certain vital characteristics in the nature of increased complexity. It is entirely conceivable and probable that such occur. Many viruses definitely appear to stimulate an increased metabolism and proliferation in the host cell early in the parasitization, and this may well represent a specialization of the parasite's metabolism to increase its opportunity for reproduction.

From the very intensive investigations that have now been carried out on certain filterable viruses, their obligately parasitic nature, their ultramicroscopic size and their intracellular specialization appear established. No characters have yet been discovered for filterable viruses that require an unique explanation. Their origin from visible microbes and their known characteristic properties are to be expected from our knowledge of the evolution of life under the conditions of parasitism.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

A SIMPLE METHOD OF DETERMINING AREAS IN MICROPHOTOGRAPHS

DETERMINATION of areas in microphotographs by the usual methods of mechanical integration is a lengthy process, requiring a skilled operator and often consuming more time than the job is worth.

By taking advantage of the fact that in a microphotograph the weight of the paper having as its surface the image of a given object varies directly as the area of the image, determination of areas can be greatly facilitated.

To apply this in the determination of the area of the image of a given object in a microphotograph, cut out of the print the image of the entire field, and weigh it. The weight of the image of the entire field on its paper is:

$$W_F = \pi r^2 D T$$

where D is the density of the paper, T its thickness and r the radius of the field as determined for the particular case. Only r and W_F need to be determined.

From the image of the entire field, cut out the image, S, whose area is desired, and weigh the paper having this image as its surface. The weight of this image on its paper is: $W_S = DT \int_a^b \int_c^d dydx$, where area of S is $\int_a^b \int_c^d dydx$. Only its weight, W_S, need be determined. The ratio $\frac{W_F}{W_S} = \frac{DT\,\pi r^2}{DT \int_a^b \int_c^d dydx} = \frac{A_F}{A_S}$ *i.e.*, the areas vary directly as the weights of the paper whose surfaces they are. From this it is obvious that the desired area, $A_S = \frac{W_S A_F}{W_F}$, where W_S and W_F were determined by weighing the paper having as its surface the respective area, and A_F was found by calculation. A more convenient form for some types of work is: Per cent. A_S is of $A_F = \frac{W_S}{W_F} \times 100$. When only relative results are desired, it is not necessary to find an arithmetical value for the area of the field.

The accuracy of this method, except for small, unpredictable errors, depends on the skill of the operator. If the cutting is done with a sharp scalpel or razor blade, held vertical, it is possible to keep the error down to about 1 per cent., this being due to the weight of silver in the emulsion, variations in the thickness of the paper, and varying moisture content in the paper.

Applications of this method outside of the field of microscopy are numerous. For example, the area of an irregularly shaped outcrop of a certain formation

can be determined by cutting the area of the outcrop from a map, and comparing the weight of the paper containing this area with the weight of the paper containing a known area, cut from the same map.

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A METHOD OF PREPARING SKELETONS OF SMALL VERTEBRATES

ALONG the entire Pacific Coast of the United States there occurs a marine isopod, *Cirolana harfordi*, which is an excellent agent for cleaning small vertebrate skeletons. I have used it a great deal in making osteological preparations, principally of fishes, and several colleagues to whom I have demonstrated the method have displayed great interest, while some have used it with considerable success.

The advantages of the method are that the finished skeleton is not disassociated, that it is cleaned within a day or two, and that no special malodorous place is required in the laboratory for storage during the process.

A fish to be skeletonized should first be skinned and eviscerated. The isopods will not attack the skin and it is practically impossible to remove it after skeletonization without tearing apart some of the smaller bones. In the case of large specimens, a little rough fleshing should be done. The specimen is then placed in a glass jar with a metal cap, such as the ones in which mayonnaise is commonly sold. The metal cap should be pierced by several 1/8 or 3/16th inch holes. These holes serve for entrance of the isopods which are small enough to leave even minute epipleurals intact and attached, while they exclude crabs which would tear the skeleton apart. The jar is placed securely under some large rock between tide marks and other stones heaped around it to keep it in place and to break up the force of waves which might damage the specimen. Twenty-four or 48 hours later the isopods have usually completed their task. The skeleton should then be gently washed in fresh water and hung up in the sun to dry. After drying, a drop of water placed on the promixal end of any bone which happens to be in an unnatural position softens the ligament and allows the bone to be rearranged.

A certain number of delicate specimens are bound to come apart in one or two places, but these may readily be patched or may serve very well as study material. A good percentage of skeletons turns out to be perfect museum material. A little practice enables any one to judge quite well the abilities of the isopods, and to balance accurately the size of the holes in the top of the jar, the amount of manual fleshing to be done, if any, and the length of time required in order to get the best results.

It should be mentioned that *Cirolana harfordi* will not attack animals which have been preserved in alcohol or formalin. Fresh material is required. The isopods also display a distaste for organisms in which putrefying bacteria have gained a good foothold. As a result 48 hours is usually their limit of activity on one specimen. In case their task is too great to be completed in this time the specimen must be thoroughly washed in order to remove all putrefying flesh, whereupon they can be induced to continue their work.

Keeping a supply of isopods in an aquarium in order to perform the work has been found to be unsatisfactory. While they eat the flesh very rapidly, they soon become satiated, and the number of individuals required to complete even a small skeleton is enormous. With the specimen placed in the ocean itself there is evidently a continuous parade of hungry workers into the jar and well-fed individuals out, resulting in the acme of efficiency.

In addition to fishes, I have made skeletons of toads, birds and small mammals. In these animals surplus pieces of ligaments should be clipped away while the skeleton is still wet. Drying the specimens in the sun for a few days generally gives them a satisfactory whiteness, but chemical bleaching agents may be used if desired.

While *Cirolana harfordi* is available to relatively few zoologists, it may well be that related forms along the Atlantic and Gulf coasts will prove equally efficient, while the fresh-water amphipods may possibly serve inland workers in the same manner.

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